The Possibilities of Nuclear Reactions Using Shaped Charges

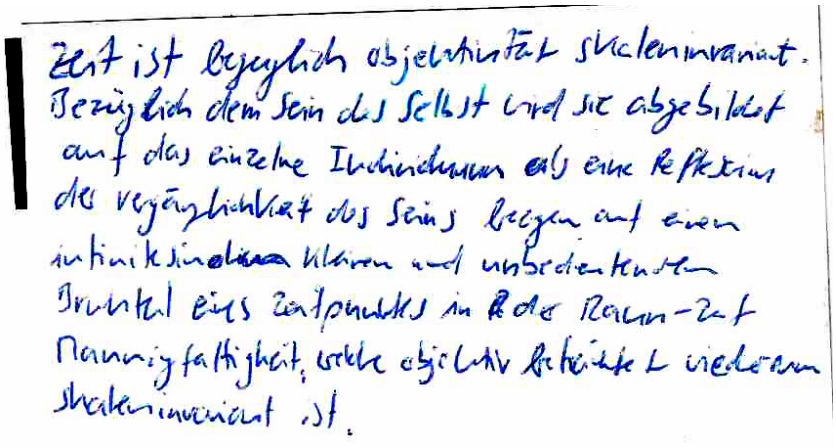
by
H. V. Hajek

(*Wehrtechnische Monatshefte*, Vol. 57, page 8–21, 1960)

$$e^{6\pi} \cdot \frac{\Lambda G \hbar}{c^3} = 10^{42} \cdot \left(\frac{a_G \cdot a_w^2}{a^2 \cdot a_s^4} \right)^3$$

$$6e^{5\pi} \cdot \frac{G \hbar H_0^2}{c^5} = 10^{42} \cdot \frac{a_w^6 \cdot a_G^3}{a^6 \cdot a_s^{11}}$$

$$e^{7\pi} \cdot \frac{\Lambda^2 G \hbar}{c H_0^2} = 6^{42} \cdot \frac{a_w^6 \cdot a_G^3}{a^6 \cdot a_s^{13}}$$


Zeit ist bezüglich objektivitäts skaleninvariant.
Bezüglich dem Sein des Selbst und sie abgebildet
auf das einzelne Individuum als eine Reflexion
der vergänglichkeit des Seins bezogen auf einen
infinitesimalen Moment und unbedeutenden
Bruchteil eines Zeitpunkts in der Raum-Zeit
Mannigfaltigkeit, welche objektiv betrachtet wiederum
skaleninvariant ist.

Contents

1 Introduction

Since the discovery of radioactivity at the beginning of this century, it has been known that much greater energies per atom are involved in all nuclear transformations than in the chemical bonding of atoms, which only affects the external electronic structure of the atom. Different transformations do hereby absorb and consume large amounts of energy, while other transformations release energy of the same magnitude. The electron volt eV is used as the energy unit for the various atoms. This corresponds to the energy that an electron or proton receives when it passes through a potential difference of one volt. The general chemical transformations, such as combustion, involve energy rates of only a few electron volts per atom. In contrast, nuclear transformations generate millions of electron volts per atom. For example, if a uranium atom U^{2351} is disintegrated under the influence of an absorbed neutron, it releases more than just one neutron; These neutrons break down other atoms, each of which releases more than one neutron, and under these circumstances the reaction propagates with lightning speed through the mass of the material that can be disintegrated. The result in a chain reaction. This is the most important invention of this century and is fundamental to the technical evaluation of atomic energy. (See O. Hahn and F. Strassmann, [7], first triggering of a chain reaction by irradiated uranium using neutrons.)

This nuclear fission was first observed when uranium was irradiated from its natural isotopic composition. However, uranium consists largely of atoms with an atomic weight of 238 and with a small presence of lighter atoms that have three fewer neutrons in the nucleus and have an atomic weight of 235. In this case, only the rare uranium 235 can be used for fission processes and not the almost 140 times more common uranium 238. In order to cause a chain reaction that can be used for an atomic bomb, a sufficient amount of pure uranium 235 must be separated. Separating uranium 235 from uranium 238 represents a particularly difficult technical problem. The two isotopes react in exactly the same way due to their relationship with other substances and therefore cannot be separated by chemical processes. Their difference is only in weight. The best methods that have been used to separate uranium 235 are the electromagnetic process or the diffusion of gases through a porous partition. This uranium 235 or plutonium 239 was used in the atomic bombs that were dropped on Japan.

Plutonium 239, for example, is produced in the following deposition process in an atomic chain reactor.

$$U_{92}^{238} + {}_{0}^{1}n = U_{92}^{239} \rightarrow Np_{93}^{239} \rightarrow P_{94}^{239}. \tag{1}$$

[1]The nucleus of each of uranium 235 (U^{235}) consists of 92 protons and 143 neutrons, for a total of 235 particles. As the arrangement of these particles within uranium 235 is somewhat unstable, the nucleus can disintegrate if it is excited by an outside source.

This plutonium is very valuable because it has the same important properties as uranium 235. If a neutron penetrates its nucleus, it disintegrates the plutonium nucleus into fragments, releasing a very large amount of energy per atom. Atomic bombs or projectiles can therefore be made from uranium 235 as well as plutonium 239. An atomic bomb must now consist of at least two separate parts and it does not matter whether the filler is uranium 235 or plutonium 239. Each of these parts must be below a certain critical size and if the bomb is to explode, one part must be pushed into the other like a bullet in a flash in order to trigger the chain reaction. The explosive power of one gram of uranium 235 is equivalent to that of 20 tons of TNT (trinitrotoluene). When it was announced after the bombing of Hiroshima that the bomb used there was more powerful than 20 000 t TNT, it became clear that all the atoms of a whole kilogram of uranium 235 had been disintegrated.

2 Nuclear disintegration and nuclear weapons

2.1 Lithium – A novel metal for nuclear weapons

One can now also use a starting material other than uranium, namely the common and very cheap light metal lithium, the lightest of all metals[2]. Its atomic weight is six and its nucleus consists of three protons and three neutrons. When it is bombarded with a neutron, which penetrates the lithium core, it disintegrates into two lighter elements: helium with two protons and two neutrons and tritium (superheavy hydrogen) with one proton and two neutrons. Both compounds are gases and are easy to separate from each other. Lithium, as found in nature, only contains 7.5 % of this type of atom with an atomic weight of six; the remaining portion consists of a counterpart with an atomic weight of seven. However, the lighter atoms do not need to be enriched because the heavy lithium has no affinity for neutrons and almost all neutrons are absorbed by the lighter variety. This new raw material, lithium, can be described as the cornerstone for new nuclear weapons. It is particularly notable for the tritium resulting from the fission process, which is now the most important component of hydrogen weapons.

The first attempts about disintegration of lithium stem from John Cockcroft and Ernest Thomas Sinton Walton in 1932, [2, 1] with the apparatus shown in Figure 1 and gave the following reaction:[3]

Bombarding a lithium nucleus with protons resulted in two helium nuclei accor-

[2]The density ρ of Lithium is $0.53\,\mathrm{g\,cm^{-3}}$ at 20 °C, whereas that of uranium-235 is approximately $19.1\,\mathrm{g\,cm^{-3}}$.

[3]This experiment was the first empirical evidence for the Einstein equation $E = m \cdot c^2$.

ding to the following equation:

$$ {}^{7}_{3}\mathrm{Li} + {}^{1}_{1}\mathrm{H} = {}^{4}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He} + \mathrm{Energy}\,. \tag{2} $$

If one breaks down the masses of this equation with precision, one will find in the first term 7.01822 for lithium and 1.00812 for hydrogen, which adds up to 8.02634. In the second term one gets 4.00390 twice for helium, so a total of 8.00780. The difference in masses is 0.01854 and represents the released energy. This energy is already considerable, since, for example, if 1 g of lithium is disintegrated this results in approximately 57 142 kWh energy.

The scheme of this lithium disintegration looks like this:

$$ \underbrace{\text{PROTON}}_{\substack{1\ \text{Proton}}} \longrightarrow \underbrace{\text{LITHIUM}}_{\substack{3\ \text{Protons}\\ 4\ \text{Neutrons}}} = \underbrace{\text{HELIUM}}_{\substack{2\ \text{Protons}\\ 2\ \text{Neutrons}}} + \underbrace{\text{HELIUM}}_{\substack{2\ \text{Protons}\\ 2\ \text{Neutrons}}}\,. \tag{3} $$

This lithium disintegration occurred with accelerated protons below 1.2×10^5 V.

The downside to this lithium disintegration is that one has to bombard the lithium core with several million projectiles before one can achieve a single atom disintegration. In this case, the energy consumption is greater than the energy gained.

2.2 Tritium and Deuterium – Neutron irradiation

Today's most effective and fastest method for disintegrating lithium and producing tritium is to introduce lithium metal into a nuclear reactor, where the metal is exposed to neutron irradiation and thus splits into helium and tritium. But one neutron is needed to form a tritium atom or also a plutonium atom, but these neutrons are only created when uranium 235 is split. The atomic weight of tritium is only three, while the atomic weight of plutonium is 239; Under these circumstances, tritium is eighty times lighter, and there would be eighty times more atoms in one kilogram of tritium in relation to one kilogram of plutonium. Therefore, eighty times more neutrons would be required to produce one kilogram of tritium. This means consuming up to 80 kilograms of plutonium to produce one kilogram of tritium.

Although other methods are not as effective for producing tritium as the one mentioned above, but they do without the use of a nuclear reactor, which is again very interesting and therefore represents new possibilities for the production of nuclear energy. For example, beryllium, which is exposed to radiation from radium, radon or polonium, is an equally good source of neutrons. By bombarding lithium with neutrons from beryllium, it can also be converted into tritium. Lithium is

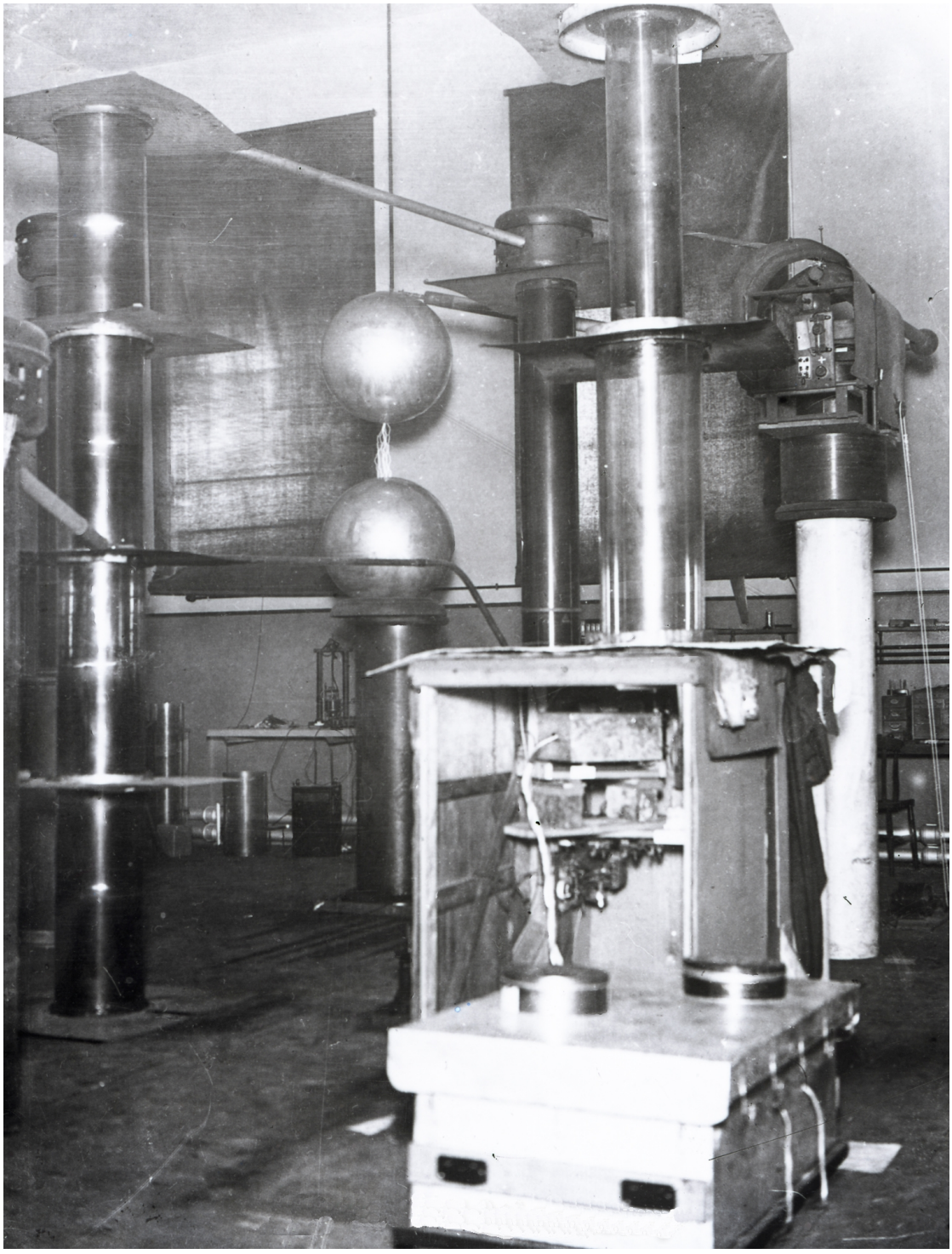


Figure 1: Photo of the Cockcroft-Walton accelerator from 1932 showing (from left to right) the voltage multiplying rectifier set, the battery (with spark discharge), the battery, the acceleration tube and the observation box, the assembly with the battery and transformer above

also not necessarily required as a raw material and the following elements also release tritium when bombarded with neutrons from beryllium: deuterium, helium 3, boron and nitrogen. This method would be interesting for the reaction of atomic hollow charges.

A kilogram of tritium produced under the above conditions develops two and a half times the explosive power of a kilogram of plutonium. However, this advantage is lost due to the instability of the tritium, which is half decomposed after about twelve years of storage and then weighs only half a kilogram. Plutonium, on the other hand, can be stored for any length of time without any noticeable loss and only after 25,000 years half of its quantity would have been transformed into uranium 235. However, this uranium 235 is itself a fissile element that will only have decayed to 50 % after nine hundred million years. For a bomb that is a thousand times more powerful than the last two uranium bombs dropped over Japan, one would need a 400 kg tritium bomb (approximately 2130 liters of liquid tritium). This bomb would correspond to the energy of 1000 kg plutonium and would have to be produced at the cost of 32×10^3 kg plutonium. This means that instead of the energy of 32×10^3 kg plutonium, an energy is obtained that only corresponds to 1000 kg plutonium.

From these consequences it can be concluded that many plutonium bombs cannot be produced in order to produce a super-H bomb, and in addition, a normal uranium 235 or plutonium 239 bomb is still required to detonate this super bomb. And one should not forget that a bomb a thousand times more powerful would only have ten times greater explosive power and thirty times greater incendiary effect. If one estimates the weight of a plutonium bomb to be 10 kg to 30 kg, one can calculate that the production of a tritium bomb can take at least 1066 or even 3200 plutonium bombs.

The tritium obtained in this way is radioactive with a half-life of 12.3 years and can therefore be easily stored up to this point.

The tritium formation reaction can look like this:

$$\left.\begin{array}{ll} \text{(a)} & {}^{6}_{3}\mathrm{Li} + {}^{1}_{0}\mathrm{n} = {}^{3}_{1}\mathrm{H} + {}^{4}_{2}\mathrm{He} \\ \text{(b)} & {}^{9}_{4}\mathrm{Be} + {}^{2}_{1}\mathrm{H} = {}^{3}_{1}\mathrm{H} + {}^{8}_{4}\mathrm{Be} \\ \text{(c)} & {}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} = {}^{3}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \\ \text{(d)} & {}^{2}_{1}\mathrm{H} + {}^{1}_{0}\mathrm{n} = {}^{3}_{1}\mathrm{H} \end{array}\right\} \tag{4}$$

This consideration has now led to the fact that in future super-H bombs (hydrogen bombs) the main mass will consist of the much cheaper deuterium, which can be enriched from ordinary water and whose only expense is electrical energy. It has

also been shown that a mixture of deuterium and tritium is the easiest mixture of atoms to ignite. It provides 3.5 times as much energy as pure deuterium and twice as much energy as pure tritium. What is also very important is that this mixture can be ignited much more quickly than any of the components alone. The three most essential foundations of a cost-effective H bomb are as follows:

1. A plutonium bomb as a fuze,
2. a relatively small amount of a deuterium-tritium mixture as a primary explosive,
3. deuterium as an actual nuclear warhead explosive.

All of these prerequisites mentioned are tied to an enormous amount of material. It is now possible to start from other prerequisites, in that, for example, nuclear reactions can be triggered in the same way, namely instead of bombarding atomic nuclei with protons, the two partners, i.e. atomic nucleus and proton, are brought next to each other so close that nuclear forces can become effective.

3 Explosive atomic nucleus compression and nuclear fusion – atomic hollow charges

The approach of the proton, in this case the hydrogen atom, to the nucleus is prevented by the positive charges present on both sides and consequently by the occurring Coulomb repulsion forces, the forces of which reach up to approx. 1×10^{-11} cm, with an atomic radius of 1×10^{-8} cm. If the two partners approach each other to 1×10^{-12} cm to 1×10^{-13} cm, nuclear forces arise that enable a hydrogen atom approaching this limit is absorbed into the nuclear sphere so that nuclear forces can occur. In order to trigger such a nuclear reaction, the reactants must have a certain initial kinetic energy in order to overcome the mutual Coulomb repulsion forces. By bringing the nuclei close enough together, the influence of the strong nuclear forces is overcome, as they only have a very short range of action. In order for the nuclei to obtain a minimum kinetic energy to enable a nuclear combustion on a microscopic scale, the reaction medium should be brought to a very high temperature. At such high temperatures, which are invariably above 1×10^{7} °C, the atoms are completely ionized. This ionization of atoms is called nuclear plasma. In the reactions that are crucial for thermonuclear combustion, two nuclei colliding with each other at high speed form an unstable intermediate nucleus that disintegrates while releasing energy. The so-called tunnel effect is important for the theory of this reaction, through which the collision partners already have a finite reaction probability for energies below the energy to overcome the intense repulsion between similarly charged particles according to Coulomb's

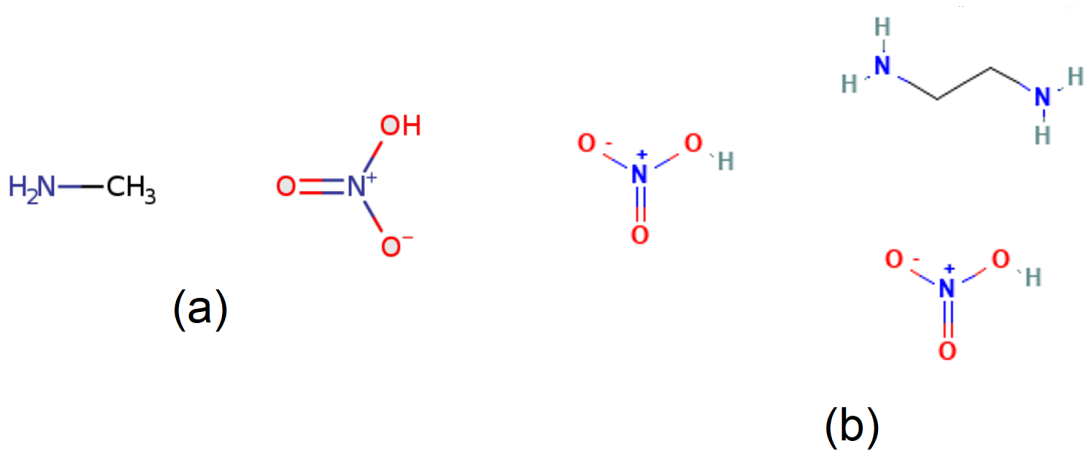


Figure 2: Lewis structure of (a) Methyl ammonium nitrate and (b) ethylenediamine dinitrate

law. The reaction cross section is determined first by the relative particle speed and then by the resonance width Γ

$$\Gamma = \frac{\hbar}{\tau}$$

of the excited intermediate nucleus, where τ is the mean lifetime and $\hbar$ is PLANCK's constant divided by 2π.

In order to force these required approach of the hydrogen nucleus to 1×10^{-8} cm to 1×10^{-13} cm (1 Å to 0.000 01 Å), pressures of over 3×10^5 atm (303 975 bar) are necessary. In addition to lithium and beryllium, uranium 233 can also be considered as a metal to be used.

These requirements were now pursued further and attempts were made to generate the correspondingly required high pressures using blasting technology. Explosives must be used in which hydrogen atoms, if possible, are in excess of the residual atoms present in the compound, or whose percentage of the total atoms is at least 50 %. The content of hydrogen atoms, based on total atoms, in commonly used explosives such as Hexogen or Nitropenta is very small. In this case one has to use amino explosive compounds or perchlorate amine salts, such as: methylammonium nitrate ($CH_6N_2O_3$, see Figure 2(a)) or perchlorate, ethylenediamine dinitrate (see Figure 2(b)), ethylenediamine diperchlorate or ethylenediamine triethylenediamine tetraperchlorate $(C_2H_{10}N_2)^{2+}(C_6H_{14}N_2)^{2+}(ClO_4)_4{}^{4-}$ etc. in conjunction with Hexogen or Nitropenta. Table 1 gives an overview of possible amino explosive compounds and their H-content in relation to particles per 100 % mass.

In order to obtain high pressures, the free energy per unit volume or unit area

that is released during the explosive reaction must be as large as possible. In general, the amount of heat released is calculated in kilocalories based on kg, but here the energy content per unit volume must be taken into account.

The energy content of an explosive system can be increased by various metal additives or compounds. Of all the chemical compounds in question, boron, lithium and beryllium compounds were used as energy-enhancing compounds in the practical experiments.

If one wants to trigger nuclear reactions using proton compression on other nuclei, such as lithium, beryllium or uranium, it is necessary, as stated above, to chose a proton concentration and the energy content, based on cm^3 or dm^3, as high as possible. The energy content in kilocalories is a given value for a certain explosive composition and cannot be increased chemically further. In this way, a specific detonation speed is obtained for the explosive compound and the maximum combustion temperature is obtained from the energy content. The detonation speed of the known explosive compounds can only be changed to a small extent by catalysts, and the practically achievable limit is $10\,000\,m\,s^{-1}$. According to recent studies, the plume speed can be set equal to the detonation speed for short distances, while at longer distances, greater than 10 cm, only one tenth of the detonation speed is obtained.

Over short distances, the plume speed depends on the total amount of explosive detonated. It is therefore based on equal distances from the explosive to be detonated, which is larger when detonating 100 kg explosive than when only 0.1 kg is detonated.

At least a hundredfold increase in the detonation speed is necessary to achieve nuclear reactions and this can only be achieved by physical means.

This requirement can be met if one performs three-point impacts on atoms in such a way that two of the atoms transfer their entire amount of kinetic energy to the third atom, so that the latter increases in kinetic energy.

Evasive swerves after the collision from b to B, b with c and therefore a collision with c due to elastic or inelastic collision is avoided by allowing the particles a and b to follow an infinite number of particles a_1, a_2, a_3, $\ldots a_n$ or b_1, b_2, b_3, $\ldots b_n$ under the same angle, so that each following particle gives off its energy to the previous one, which in turn acts on c_1, c_2, c_3, $\ldots c_n$.

This results in atoms that move towards the direction B at super-detonation speed. This atom beam aimed towards B is only detonated in a second shaped charge when it is contained in the latter, so that the above process repeats itself like a cascade reaction. If these requirements are met, a shaped charge jet S_n, which is shot through the hollow charges H_1, H_2, H_3, $\ldots H_n$ will be obtained, whose

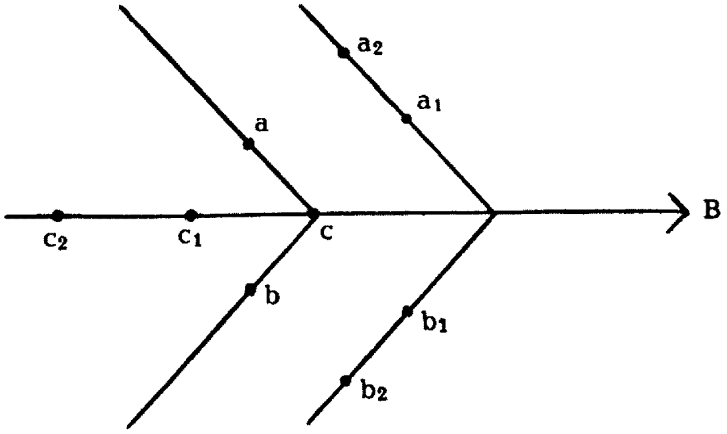


Figure 3: Schematic representation of the triple collision of atoms a, b and c towards point B

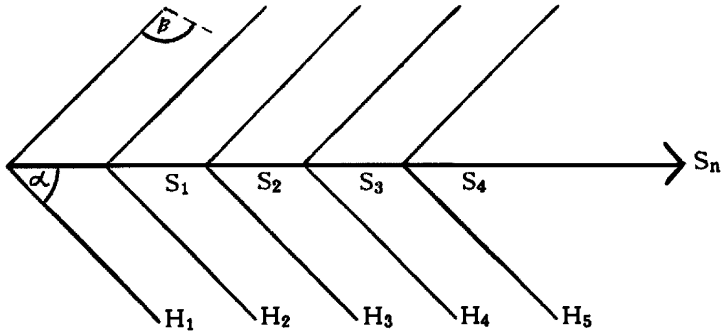


Figure 4: Shaped charge jet S_n, consisting of accumulated individual partial shaped charge jets S_n (n = 1, 2, 3, ...) shot through the hollow charges H_n

particle speed is increased multiple times of the original one.

If one uses two such detonation accelerators shown in Figure 3 and Figure 4 and shoot them at each other, one can obtain high pressures and temperatures at the focal point.

When two detonation plumes collide, temperatures above 1×10^5 °C arise in very short time intervals. With the combination of a detonation accelerator and vapor compression, it is possible to bring the two reactants so close to each other that nuclear reactions can occur.

For example:

D_1 and D_2 = detonation accelerator
B = focus of D_1 and D_2

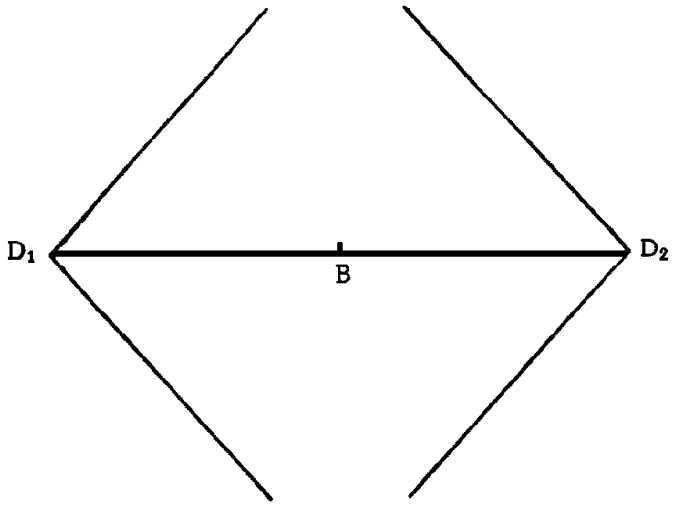


Figure 5: Collision of two detonation plumes using two detonation accelerators D_1 and D_2 at focal point B

In order to achieve the high temperatures necessary for these nuclear reactions to occur with the help of the released energy of a chemical reaction, it is absolutely necessary to create an extraordinarily high temperature in the presence of strong pressures.

A high temperature arises inside a combined shaped charge as a result of the collision of various detonation waves and plume compressions. The temperature is higher the more tightly sealed the shaped charge is, that is, if there is a vacuum in it. If one detonates an ordinary explosive, such as Hexogen-Trotyl 60/40, which is present in rod form under a vacuum of 0.001 mm Hg pressure, one can measure a temperature of 1×10^5 °C and even more.

The French researcher Jouguet, famous for his thermo-hydrodynamic theory, came to the conclusion that high temperatures occur in the shock waves at reduced pressure, [9, 10].

Consider the values given in Table 2 as an example.

pressure, atm	Temperature, °C
10	20 300
1	38 000
0.1	58 000
0.01	77 000
0.001	94 000

Table 2: Relationship between reduced pressure and temperature in shock waves

One may notice here how quickly the temperature rises sharply the more the pressure is reduced.

When using combined vacuum shaped charges and in the presence of at least 0.001 mm Hg pressure, the temperature at the focal point of the colliding waves can increase due to accumulation to a million degrees or more.

With ordinary shaped charges, the jet speed is based on a massed concentration of energy. In this case the jet speed is greater than the detonation speed and can reach a value of $12\,\mathrm{km\,s^{-1}}$ when using high explosives. The kinetic energy that the liner material has acquired after the explosion is concentrated on a certain part in the shaped charge jet, and the smaller this part can be kept, the greater the energy density becomes. This energy density of the shaped charge jet can be viewed as the largest next to nuclear fission. Now, according to Schardin, the compressibility of the shaped charge's liner material forms a limit to achieve high jet speeds. According to the hydrodynamic theory, the liner material is treated as an incompressible liquid and would have to achieve high material speeds with a certain small jet mass. In theory and practice, the compressibility κ_L of the liner material, which is defined as the reciprocal of the bulk modulus K (see Table 3), limits the highest achievable jet speed v_j according to

$$v_j \propto \frac{1}{\kappa_L}$$

Due to the extremely high pressures that occur within the jet zone, significant compactions are formed in the liner materials, which in turn enable a shaped charge jet-less impact. When using copper and aluminum, approximately $20\,\mathrm{km\,s^{-1}}$ speed was measured and iron and lead give a much lower speed value due to their higher compressibility. In their experiments, the Americans found a particularly cheap metal, beryllium, with a density of $1.848\,\mathrm{g\,cm^{-3}}$ and greater strength than the

other liners made of aluminum and copper, which goes along much faster in the shaped charge explosion. With these liners made of beryllium and in particular rotationally symmetrical shaped charges in which a vacuum was introduced, material speeds of $90\,\mathrm{km\,s^{-1}}$ could be observed. Beryllium offers a special advantage here, namely due to its low atomic weight of 9.012 and its very low specific heat capacity of only $0.434\,\mathrm{cal\,g^{-1}\,°K^{-1}}$. The atomic heat according to the rule of Dulong-Petit, the product of atomic weight and specific heat capacity, can be given as $3.9\,\mathrm{cal\,°K^{-1}}$, which equals $1.97 \cdot \mathscr{R}$, where $\mathscr{R}$ is the gas constant with a value of $1.987\,\mathrm{cal\,mol^{-1}\,°K^{-1}}$. These facts would present beryllium as a favorable shaped charge material if it were not for the fact that the metal is very brittle and makes it difficult to process. The very high price should also be taken into account, which at 130 dollars per kilogram hardly allows for a wide range of applications. But if one considers again that with beryllium liners one can achieve matter speeds of $90\,\mathrm{km\,s^{-1}}$ and now connects this to the temperature again, then temperatures should be expected that suggest nuclear processes. But if one now uses the light metal lithium for comparison, one gets much better values and possible uses as a shaped charge liner. The speed of matter could be increased beyond $90\,\mathrm{km\,s^{-1}}$ in order to then increase the energy concentration so that nuclear reactions could perhaps be triggered.

Lithium is very easy to process compared to beryllium, it is a fairly tough metal and is the lightest solid material among the metals. Its density is only $0.534\,\mathrm{g\,cm^{-3}}$ with an atomic weight of 6.94 and a specific heat of $0.848\,\mathrm{cal\,g^{-1}\,°K^{-1}}$. According to the rule of Dulong-Petit, the atomic heat is equal to $5.9\,\mathrm{cal\,°K^{-1}}$, which equals $2.96 \cdot \mathscr{R}$. The price is 35 dollars per kilogram.

The lithium metal as a liner for shaped charges is now the most favorable factor for achieving high jet speeds. Due to its extremely low density of only $0.534\,\mathrm{g\,cm^{-3}}$ and an atomic weight of only 6.94, it is accelerated much faster than beryllium, aluminum or copper liners in the shaped charge explosion. The compressibility of the lithium liner metal reaches the lowest achievable tolerance to simultaneously generate the highest jet speeds.

Due to these facts, only lithium metal can be used as a liner in atomic hollow charges to initiate possible nuclear fission reactions.

The shaped charge reaction with its essential processes such as the formation of the shaped charge jet and the deformation of the metallic liner has been completely elucidated by Schardin in recent years using X-ray flash photography and in conjunction with the Kerr cell camera[4], [13]. These highly interesting research

[4]In the Kerr cell camera, the Kerr cell is used as a characteristic, which, when placed under a high voltage, causes the polarization plane of the light to rotate and enables the recording of 8 million images per second. See `https://en.wikipedia.org/wiki/Kerr_effect`

results relate particularly to the detonation process of various types of shaped charges with conical metal liners.

In order to technically initiate a thermonuclear reaction in combined shaped charges, correspondingly high temperatures and radiation intensities must be present. According to SÄNGER, [17, 16], there is already a great possibility in the detonation wave of solid or liquid explosives, which can bring matter to the very high pressures of 1×10^6 atm and simultaneous temperatures of 1×10^5 K. In the center of converging cylindrical or spherical detonation waves, these pressures and temperatures can be increased very significantly in limited volume areas. As the detonation waves approach the convergence center, the flow cross sections decrease quite sharply. In contrast, the detonation speed as well as the pressures and temperatures increase very sharply and can tend to reach infinity. In a plane detonation shock wave, the molecules are compressed up to their covolume so that the detonation plasma is present in the form of a condensate. (Regarding a discussion about the covolume see [11].) If further compression is to be achieved, this can only be done by engaging the electron shell, or deforming the electron orbits and ionization towards the next levels of matter, such as atomic gas and electron gas. In this case the temperature can be linked to the speed of a corpuscle. As a result of these processes, the atomic diameters decrease very sharply and when the last electron is separated, in which the transition to the electron-proton gas is completed, the free path lengths can instantly change by many powers of ten, so that the basis of the initial compression shock with its dimension of only a few path lengths is eliminated. These considerations now raise the possibility that matter in the very narrow temporal and spatial range of the convergence center reaches states that can lead to thermal nuclear reactions.

The onset of the nuclear reaction requires a certain ignition temperature, which can be derived from the following equations.

The possibility of ignition can be described by the following equation:

$$\frac{E}{I} \geqslant 1\,. \tag{5}$$

E means the energy production of the substance to be ignited and I means the energy losses to its surroundings.

One can now assume that at high temperatures only radiation losses can be taken into account. If a spherical body with a radius r radiates black[5], the following

[5]A black body is an idealized physical body that absorbs all incident electromagnetic radiation, or stated equivalently, a body that emits maximized thermal radiation.

equation can be used for the radiation emerging from the surface:

$$I_S = 4\pi r^2 \cdot \sigma \cdot T^4 \,. \tag{6}$$

σ is the STEFAN-BOLTZMANN constant with a value of approximately $5.670\,38 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$ and T is the absolute temperature.

The energy production of thermonuclear material can be given by the following equation:

$$E = \frac{4}{3}\pi r^3 \cdot \rho^2 \cdot a \cdot \frac{1}{\sqrt[3]{T^2}} \cdot e^{-b \cdot \frac{1}{\sqrt[3]{T}}} \,. \tag{7}$$

The density is denoted by ρ and a and b are the constants denoting nuclear reactions. If Equation 6 and Equation 7 are now inserted into Equation 5, the following equation is obtained:

$$\frac{E}{I} = f(T, \rho \cdot r \geqslant 1) \,. \tag{8}$$

Radii of astronomical magnitudes are obtained from technically manageable pressures and densities. Now hydrogen or its isotopes do not emit black-body radiation and are characterized by a lower radiation than all other substances. If gray-body radiation[6] is assumed instead of black-body radiation, the following other equation can be derived for Equation 8:

$$\frac{E}{I_g} = f(T) \geqslant 1 \,. \tag{9}$$

The critical radius r is no longer included here and there is now only a critical temperature T, which can be calculated as follows and represents the desired thermonuclear ignition temperature:

$$f(T) = 1 \,. \tag{10}$$

Within these processes, the thermonuclear material can be detonated at the required high temperature even in a small area of space, such as the convergence center of a combined shaped charge bomb.
If we now start from the idea that the nuclear combustion plasma, like any gas in

[6] A gray body is an imperfect black body. It is a physical object that partially absorbs incident electromagnetic radiation. The ratio of a gray body's thermal radiation to a black body's thermal radiation at the same temperature is called the emissivity of the gray body. The emissivity of a black body is unity, while that of a gray body is larger than 0 and smaller than 1. The emissivity is a function of the geometry of the radiative surface, its physical properties, and the wavelength.

equilibrium, not only exhibits the most common particle speed with a value of

$$v = \sqrt{\frac{3k_B T}{M}}$$

determined by the temperature T, but also all other particle speeds between zero and infinity, where the velocity distribution is given by the MAXWELL-BOLTZMANN relationship, particle velocities can occur at particularly low temperatures that can be sufficient to overcome the repulsive COULOMB's potential within the atomic nuclei. As the temperature increases, such particle energies become more and more intense, so that their energy production increases sharply.

In the case of a completely adiabatic closed volume of the nuclear combustion plasma, the initially rare nuclear reactions can cause a significant increase in the gas temperature. This increase in turn causes a greater nuclear reaction rate, which is associated with a further increase in temperature. A continuation of these cascading reactions can lead to an explosive nuclear combustion of the entire plasma, which then triggers the desired nuclear fusion. Under these conditions, the ignition temperature of the thermonuclear reactions could be kept as low as desired.

G. GAMOW and C. L. CRITCHFIELD have calculated the numerical values for these thermonuclear reactions according to the energy release of the nuclear transformations in question, [4]. Below are some calculations (Table 4) that would be relevant for a possible shaped charge nuclear reaction.

Material	bulk modulus K, GPa
Lithium	11
Lead.....	46
Aluminum.....	76
Beryllium.....	130
Copper	140
Steel.....	160
Tantalum.....	200

Table 3: Bulk modulus K for different liner materials

Compound	formula	H-content, %	remarks
methylammonium nitrate	$CH_6N_2O_3$	50.0	
Cast Explosive	–	47.6	US 8,663,406 34.9 wt.% DETN 33.4 wt.% EDD 25.4 wt.% MeNQ 6.3 wt.% NQ
methylamine perchlorate	CH_6ClNO_4	46.2	
methylammonium perchlorate (MAP)	CH_6NClO_4	46.2	
diethylenetriamine trinitrate (DETN)	$C_4H_{16}N_6O_9$	45.7	
ethylenediamine dinitrate (EDD)	$C_2H_{10}N_4O_6$	45.5	
ethylenediamine triethylenediamine tetraperchlorate (ETT)	$C_8H_{24}N_4O_{16}Cl_4$	42.9	$v_d = 8956\,\mathrm{m\,s^{-1}}$ (density $\rho = 1.873\,\mathrm{g\,cm^{-3}}$)
ethylenediamine diperchlorate	$C_2H_{10}N_2Cl_2O_8$	41.7	
Hexogen (RDX)	$C_3H_6N_6O_6$	28.6	commonly used explosive
Nitropenta (PETN)	$C_5H_8N_4O_{12}$	27.6	commonly used explosive

Table 1: Amine and perchlorate amine explosives listet with their content of H atoms in particle-% (denominator of 100) as percentage by mass explosives; last two ones for comparison

Reaction	MeV	Maximum rate of energy per unit mass at constant density, $\rho = 1\,\mathrm{g\,cm^{-3}}$		Maximum energy rate per unit volume at constant pressure, $p = 1\,\mathrm{atm}$		Burnout time at 1 atm
		T_{opt}	ΔE_{max}, $\mathrm{cal\,g^{-1}\,s^{-1}}$	T_{opt}	ΔE_{max}, $\mathrm{cal\,g^{-3}\,s^{-1}}$	s
${}_1^2\mathrm{H} + {}_1^2\mathrm{H} = {}_2^3\mathrm{He} + {}_0^1\mathrm{n}$	3.2	9.81×10^{9}	6.98×10^{17}	1.53×10^{8}	6.60×10^{-4}	3.61×10^{-1}
${}_1^3\mathrm{H} + {}_1^2\mathrm{H} = {}_2^4\mathrm{He} + {}_0^1\mathrm{n}$	17.6	1.18×10^{10}	9.10×10^{18}	1.83×10^{8}	1.08×10^{-2}	1.07×10^{-1}
${}_1^3\mathrm{H} + {}_1^3\mathrm{H} = {}_2^4\mathrm{He} + 2\,{}_0^1\mathrm{n}$	11.4	1.48×10^{10}	4.25×10^{18}	2.31×10^{8}	4.02×10^{-3}	1.2×10^{-1}
${}_3^6\mathrm{Li} + 0.5\,{}_2^1\mathrm{H} = {}_2^4\mathrm{He} + {}_2^4\mathrm{He}$	22.1	1.33×10^{11}	1.44×10^{19}	2.07×10^{9}	2.97×10^{-4}	1.72×10^{-1}

Table 4: Results of calculations that would result for a fictitious shaped charge nuclear reaction

Based on the preceding requirements, the production and detonation of a chemical bomb with nuclear disintegration phenomena is due to the formation of several shaped charges into which a high vacuum is introduced. The shaped charge explosion offers the best and easiest way to generate high temperatures and pressures. This chemical-physical reaction, which takes place in a convergence center that is very limited in time and space, still offers the most successful way to induce artificial thermal nuclear transformations, especially between the respective matter regarding the fastest reaction and the lowest thermonuclear ignition temperatures, such as deuterium and tritium, as well in conjunction with lithium.

When the detonation waves, plume compressions and jet velocities collide, an extremely high temperature is formed in the center of convergence of these shaped charges, which is connected absolutely to the detonation particles of the explosive charge and thus leads to molecular aggregation as a result of addition due to the unusually high velocities. The velocity of matter in these combined shaped charges can reach a speed of $1 \times 10^2\,\mathrm{km\,s^{-1}}$ and more.

In order to increase the plume compression and pressure inside these shaped charges, they can be surrounded with a heavy material, for example lead, iron, etc., which compresses the entire material at the moment of the explosion and thus prevents the premature radiation of energetic illumination. A similar tamper/confinement can also be achieved by a special layer of explosive that is located around the shaped charge bomb and which allows a fraction of the shaped charge explosion to detonate inwards using a special ignition method. This very important compression method is intended to keep the possible energy losses to the environment of the shaped charges smaller than the energy production of the plasma.

Under these enormous energy concentrations and temperatures, the nuclei located in the reaction or convergence center of the combined shaped charges can be disintegrated and thus atomic energy can be released.

The following nuclear reactions would be possible for a shaped charge nuclear explosion:

$$\left.\begin{array}{ll} \text{(a)} & {}_1^1\mathrm{H} + {}_1^2\mathrm{H} = {}_2^3\mathrm{He} + 5\,\mathrm{MeV} \\ \text{(b)} & {}_1^2\mathrm{H} + {}_1^2\mathrm{H} = {}_2^3\mathrm{He} + {}_0^1\mathrm{n} + 3.2\,\mathrm{MeV} \\ \text{(c)} & {}_1^2\mathrm{H} + {}_1^2\mathrm{H} = {}_1^3\mathrm{H} + {}_1^1\mathrm{H} + 4.0\,\mathrm{MeV} \end{array}\right\} \tag{11}$$

The reaction under Equation 11(a) can be initiated at a lowest core ignition temperature of $4 \times 10^5\,^\circ\mathrm{C}$, while reactions Equation 11(b) and (c) have approximately the same reaction probability and require an ignition temperature of $8 \times 10^5\,^\circ\mathrm{C}$. Gross, [5, 6], in his study of the Fonberg effect already calculated temperatures

of 4.09×10^5 °C for a shaped charge with a cylinder of 15 cm height and 8 cm width, with an inner cone of 10 cm height and with an explosive weight of 1 kg Pentrinite (50/50), an assumed detonation time of 1.25×10^{-5} s and a circular impact area of 2 cm diameter.

In order to enable reactions (a) to (c) according to Equation 11 in a combined shaped charge bomb, a very hydrogen-rich explosive compound must be used. The High Explosive could be composed of Hexogen, boron, ethylenediamine dinitrate and lithium hydride or deuteride. The presence of, for example, lithium hydride in the explosive mixture is essential to ensure the necessary high hydrogen concentration. Shaped charge liners are made of lithium and the reaction center of these vacuum shaped charges contains deuterium or lithium deuteride-lithium hydride. The vacuum should have a minimum pressure of 0.001 mm Hg. A special insulation of the shaped charge bomb prevents energy losses to the environment. The shaped charge design must be optimized to an extreme geometric standard and brought to a maximum jet density.

Now the following cyclic reaction process could also occur in the presence of lithium deuteride in the shaped charge combination.

$$\begin{aligned} \text{(d)} \quad & {}^{3}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} = {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} \\ \rightarrow\ & {}^{1}_{0}\mathrm{n} + {}^{6}_{3}\mathrm{Li} = {}^{3}_{1}\mathrm{H} + {}^{4}_{2}\mathrm{He} \end{aligned}$$

The light lithium isotope ^{6}Li is converted into helium and tritium when a neutron hits it; the tritium formed immediately reacts with the deuterium to form helium and a neutron. With this equation the chain process would be initiated. However, since this reaction equation requires a much higher ignition temperature and the lowest possible ignition temperature should always be used for shaped charge explosions, the following second cyclic reaction equation can be used:

$$\begin{aligned} \text{(e)} \quad & {}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} = {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} \\ \rightarrow\ & {}^{1}_{0}\mathrm{n} + {}^{6}_{3}\mathrm{Li} = {}^{3}_{1}\mathrm{H} + {}^{4}_{2}\mathrm{He} \end{aligned}$$

Reaction (b), which has a very low ignition temperature of 8×10^5 °C, was inserted into equation (e). In this case, the light lithium isotope ^{6}Li is located in the reaction center of the shaped charges in the form a spherical shape, which in turn contains deuterium or lithium deuteride. It would also be worth considering incorporating equation (a) into the cyclic reaction with only 4×10^5 °C ignition temperature in order to also allow a transformation of the lithium isotope ^{6}Li to obtain helium and tritium.

The reaction described under (e) develops a strong energy tone and occurs even at very low deuteron energy. Now the deuterium contained in the reaction can

undergo a secondary reaction with the simultaneous formation of tritium.

$$\text{(f)} \quad {}^{2}_{1}\mathrm{H} + {}^{1}_{0}\mathrm{n} = {}^{3}_{1}\mathrm{H}$$

The deuterium or lithium deuteride, which is contained inside the lithium sphere in reaction (d) or (e), transforms into a completely ionized plasma even at very low temperatures of $1 \times 10^5\,^{\circ}\mathrm{C}$ and causes very high and increasing pressures that can exceed 1×10^6 atm.

Since in reactions (d) and (e) the light lithium isotope ^{6}Li is transformed into helium and tritium by the impact of a neutron, thus initiating the chain reaction, it would now be possible in order to activate this reaction, to integrate a special neutron source into the shaped charge nuclear process. A very simple and energy-rich neutron source is obtained when beryllium powder is mixed with radium sulfate, thereby producing radon. The radium emanation acts on the atomic nuclei of beryllium through α-decay which is emitted from it and ejects neutrons out of them with a very high energy of 13.7 MeV. The beryllium atom thereby changes into a carbon atom.

$$\text{(g)} \quad {}^{9}_{4}\mathrm{Be} + {}^{4}_{2}\mathrm{He} = {}^{12}_{6}\mathrm{C} + {}^{1}_{0}\mathrm{n}$$

Now, since the neutrons have no charge, they also penetrate into the highly charged nuclei of the heavy elements, which make it difficult for α-decay and proton radiation to penetrate. In many cases, even slow neutron beams, which only have the normal thermal velocity of gas molecules, are particularly effective. A distinction is made between the thermal neutrons already mentioned, with an energy of the order of 0.025 eV, which correspond approximately to a speed of $2000\,\mathrm{m\,s^{-1}}$, and fast neutrons, whose energy is significantly larger and can reach approximately million electron volts. Since the neutron does not require much energy to penetrate the nucleus, neutrons with a low velocity can also be used. These factors greatly facilitate the shaped charge core process, which has now found its final solution through these combined reaction processes.

The additional neutron source is concentrated in the reaction center at the moment of the shaped charge explosion and, together with the tremendous energy concentrations and temperature of the combined shaped charge reaction, releases the atomic energy.

The reaction equation with the additional neutron source can look like this:

$$\begin{aligned} \text{(h)} \quad & {}^{9}_{4}\mathrm{Be} + {}^{4}_{2}\mathrm{He} = {}^{12}_{6}\mathrm{C} + {}^{1}_{0}\mathrm{n} \\ & {}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} = {}^{3}_{1}\mathrm{He} + {}^{1}_{0}\mathrm{n} \\ \rightarrow \; & {}^{1}_{0}\mathrm{n} + {}^{6}_{3}\mathrm{Li} = {}^{3}_{1}\mathrm{H} + {}^{4}_{2}\mathrm{He} \end{aligned}$$

With this equation, the cyclic chain process in the shaped charge atomic bomb would now also be initiated, as mentioned under (e).

Beryllium could also be used in the shaped charge process and with the presence of ${}^{9}_{4}\mathrm{Be}$ in the reaction center of the combined shaped charges, the following reaction could be initiated by bombarding hydrogen-rich explosives:

$$ {}^{9}_{4}\mathrm{Be} + {}^{2}_{1}\mathrm{H} = {}^{3}_{1}\mathrm{H} + {}^{8}_{4}\mathrm{Be} \tag{12} $$

In addition to lithium and beryllium, the uranium isotope U 233 could also be of interest for a shaped charge nuclear reaction. Due to its very small critical mass, it has a wide range of applications and is already used in nuclear weapons and rockets today.

The production of U 233 according to Equation 13 is based on natural thorium, which consists of seven isotopes, of which the most extensive is thorium 232. If this Th 232 is exposed to the neutrons of a nuclear reactor, it transforms into thorium 233, which is radioactive, while absorbing a neutron. This thorium is in turn transformed into protactinium 233 by β-decay with a duration of 23 minutes; a second β-decay with a duration of 27 days results in the decayable uranium 233. These operations can now be carried out on an industrial scale basis in the nuclear reactors.

$$ \left.\begin{aligned} {}^{232}_{90}\mathrm{Th} + {}^{1}_{0}\mathrm{n} &\rightarrow {}^{233}_{90}\mathrm{Th} \\ {}^{233}_{90}\mathrm{Th} \rightarrow \beta\ 23\,\mathrm{Minutes} &\rightarrow {}^{233}_{91}\mathrm{Pa} \\ {}^{233}_{91}\mathrm{Pa} \rightarrow \beta\ 27\,\mathrm{Days} &\rightarrow {}^{233}_{92}\mathrm{U} \end{aligned}\right\} \tag{13} $$

4 Final Discussion

This previous treatise on the possibilities of nuclear reactions using shaped charges is only a certain excerpt from the theories and experiments that the author carried out as an expert at the French Ministry of Defense between 1946 and 1949. This atomic shaped charge process was examined and withheld at the time by the French High Commission for Atomic Energy within the War Ministry. (Un explosif à désintégration atomique – Letter from the "Ministère des Forces Armées – Direction des Poudres", 1948.) Due to military-technical regulations and reasons, it is currently not possible to provide precise information about the sequence of the tests and the subsequent follow-up. A further publication with photographs, drawings and a precise sequence is planned in due course.

Some time later, in 1951, the American researcher Fonberg published a short note on nuclear reaction in the explosion of shaped charges in the series "*Journal of Chemical Physics*", [3]. In his experiments, Fonberg used an explosive made

from ammonium nitrate and gelatin (nitroglycerin) that was as rich in hydrogen as possible. The French researcher Tauzin repeated the experiments of Fonberg, [18], as did the American researchers Plain, McLaughlin and Odencrantz at the same time, [12]. However, Tauzin and Plain used low-hydrogen explosives, for example 88 % hexogen and 12 % paraffin, which in turn speaks against the chances of success. In 1954 Stettbacher, [14], in his publication on "Explosives and their effects in theory and practice" gave some explanations about molecular ignition using shaped charges, as well as in a later note "On the chemothermal attack to the atomic nucleus", [15]. Stettbacher used pentrinite as an explosive in his experiments[7], which also does not contain enough hydrogen. His two shaped charge tests had to be negative because there was no complete tamper/confinement of the shaped charges in order to reduce the energy losses to the environment to the minimum tolerance. A vacuum was also missing to achieve the maximum energies and temperatures. In 1955 the author published a short article on "atomic hollow charges", [8], and in 1956 the Brazilian military chemist Gross published a study on the Fonberg effect, [5, 6] with various presentations about the possibilities of nuclear reactions. Gross again used hydrogen-rich explosives in his experiments, mainly ammonium nitrate in combination with lithium nitrate and deuterium oxide. These nitrate compounds hold out the prospect of possible nuclear reactions between protons, deuterons and lithium, which can take place even at fairly low energy concentrations, such as in shaped charges. Unfortunately, Gross did not use any tamper/confinement in his shaped charge tests, so all the energy concentrations were released into the environment. In addition, the vacuum used in the shaped charge of only 9 mm Hg was completely inadequate for an increased energy concentration in the shaped charge jets and also inadequate for an increase in temperature.

From these statements and facts above it can be seen that for a long time various states have wanted to achieve a thermal-nuclear nuclear reaction of matter using the energies of a chemical shaped charge explosion and have perhaps already achieved it.

[7] Pentrinite is a mixture of 20 % to 50 % Nitropenta (PETN, Pentrite, Pentaerythrityl tetranitrate) with 80 % to 50 % Nitroglycerin.

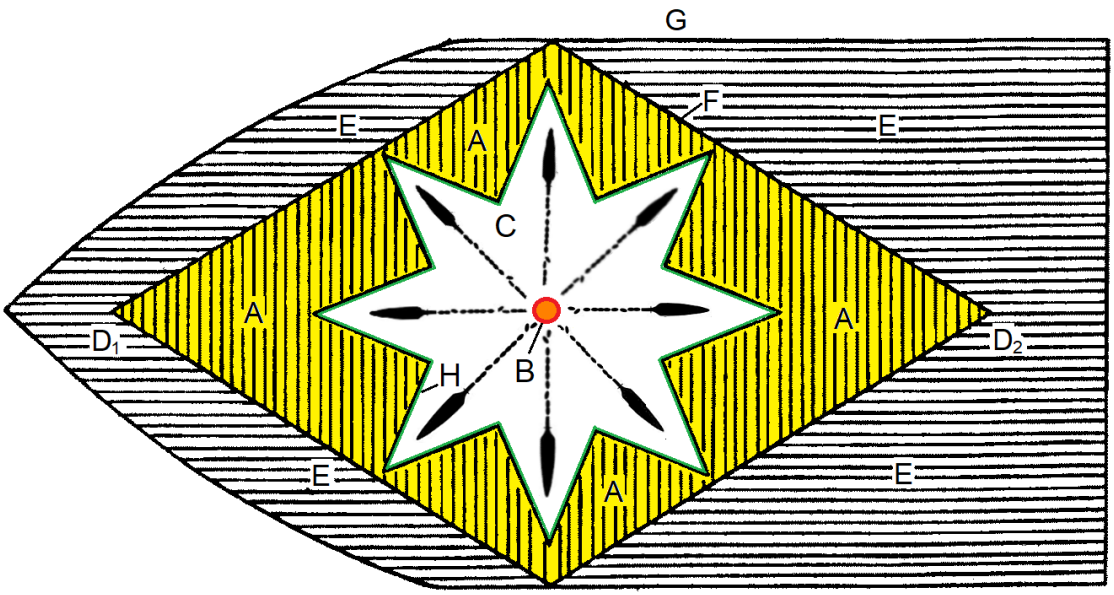


Figure 6: Schematic representation of a atomic hollow charge with components initiating the hollow charge core process

Overview of a combined atomic reaction-shaped charge
(Only as a scheme)
Legend:

D_1 and D_2 = shaped charge combination
B = reaction center of the shaped charges, where, depending on one's choice, lithium, lithium hydride and deuteride, beryllium and uranium 233 can be located
C = high vacuum of 0.001 mm Hg
A = High explosive (Hexogen – ethylene diamine dinitrate – boron – lithium hydride, etc.)
H = Lithium metal liner
E = tamper/confinement with explosives through special ignition
F = lining of jets of the outer surface of the shaped charges
G = Bomb – rocket or grenade

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